Appendix S
Live Fire Testing

S–1. Overview of live fire testing

This appendix provides general guidelines for the planning, conduct, and documentation of the testing portion of Army full-up, system level (FUSL) LFT&E programs. The responsible testing agency (generally ATEC's DTC for ground systems, ARL/SLAD for aviation systems and SMDC for integrated missile defense, intercontinental ballistic missiles, space launch, and high energy laser systems) has the overall responsibility of ensuring that assigned programs are conducted in a timely and cost efficient manner while maintaining the integrity of the test process. See appendix J for LFT&E strategy development discussion.

S–2. Live fire test definitions

a. The term *full-up system level testing* is that testing that fully satisfies the statutory requirement for "realistic survivability testing" or "realistic lethality testing" as defined in Section 2366, Title 10, USC. The Defense Acquisition Guidebook further defines FUSL testing as follows:

(1) Vulnerability testing conducted, using munitions likely to be encountered in combat, on a complete system loaded or equipped with all the dangerous materials that normally would be on board in combat (including flammables and explosives), and with all critical subsystems operating that could make a difference in determining the test outcome; or

(2) Lethality testing of a production representative munition or missile, for which the target is representative of the class of systems that includes the threat, and the target and test conditions are sufficiently realistic to demonstrate the lethal effects the weapon is designed to produce.

b. Survivability is the capability of a system and crew to avoid or withstand a manmade hostile environment without suffering an abortive impairment of its ability to accomplish the designated mission. Survivability consists of susceptibility, vulnerability, and recoverability. The focus of the LFT program is vulnerability (that is, kill given a hit).

(1) Susceptibility is the degree to which a weapon system is open to effective attack due to one or more inherent weakness. Susceptibility is a function of operational tactics, countermeasures, and probability of enemy fielding a threat.

(2) Vulnerability is the characteristic of a system that causes it to suffer a definite degradation (for example, loss or reduction of capability to perform its designated mission) as a result of having been subjected to a certain (that is, defined) level of effects in an unnatural (that is, manmade) hostile environment.

c. Recoverability is the ability to take emergency action, following combat damage, to prevent loss of the system, to reduce personnel casualties, or to regain weapon system combat mission capabilities.

d. Lethality is the ability of a munition or directed energy weapon to cause damage that will cause the loss or a degradation in the ability of a target system to complete its designated mission(s).

e. Covered System is a major system that is user-occupied and designed to provide some degree of protection to its occupants in combat, or a conventional munitions program or missile program. Included as covered systems are conventional munitions programs for which more than one million rounds are planned for acquisition and a modification to a covered system that is likely to affect significantly its survivability or lethality.

f. Building-block approach is a strategy for vulnerability/lethality testing that generally begins with component level testing and progresses through sub-system, ballistic hull and turret, system level testing, and culminates in a FUSL LFT.

S–3. Live Fire Test Detailed Test Plan

The LFT DTP provides explicit instructions for the conduct of the LFT. (See para 6–29.) It is prepared by the Live Fire tester and is derived from and implements the test conditions and data requirements in the EDP. The format and content of the LFT DTP can vary depending on the nature of the individual LFT (for example, component LFT, subsystem level LFT, or FUSL LFT). As a minimum, the DTP for a FUSL LFT should contain individual sections that address the major categories listed below:

a. Cover Page. The cover page provides the name of the system, the activity/agency responsible for preparation of the plan, the date, plan classification, and applicable distribution statements.

b. Coordination Sheet. The coordination sheet contains the signature of Army and DOT&E approval authorities.

c. Administrative Information. A page providing administrative information on the position, name, organization, telephone number, and electronic mail addresses of key LFT&E personnel

d. Introduction. The introduction contains a summary description of the test program, the principal participants and their roles, the test item (system) description, the test objectives, and any other information that supports LFT.

e. Test conduct. This section covers how the test will be conducted; which threats or targets are being used; what surrogates, if any, will be used; what procedures will be used to ensure test discipline; how threats will be fired/launched; and what potential lack of realism may result from the absence of components, from use of surrogate components, from the inerting of fuzes on stowed ammunition, and so forth. A tabular listing of all threats/munitions to

be fired and target impact conditions/locations will be provided via summary tables; pictorial representations of each target impact location and attack angle will also be provided. Finally, the procedures to be used for the crew casualty and system damage assessments will be described.

f. Additional Information. Additional information will be integrated into the body of the DTP or provided as individual appendices to address subjects such as the following:

(1) *System configuration.* This information, which requires input from the system PM, describes the system configuration and its fidelity (that is, how the test item compares to the production item that is expected to be fielded). All stowage plans for full-up targets will be pictorially presented to show locations and quantity of items stowed onboard as configured for combat. These stowage plans will be approved by the combat user for U.S. systems and by the intelligence community for foreign systems, before they are incorporated into the LFT DTP.

(2) *Instrumentation plan.* The instrumentation plan describes the instrumentation suite required to record test conditions and measure system response (for example, projectile striking velocity, fuel temperature, and component acceleration). The tester will define specific instrumentation requirements based on the SEP/EDP data requirements.

(3) *The operational security (OPSEC) plan.* This plan is included as part of the DTP to ensure that all test participants are aware of the security aspects of the LFT and how the data are to be handled. Furthermore, the high visibility and sometimes controversial nature of LFT requires strict compliance with OPSEC safeguards.

S–4. Live Fire Test Detailed Test Plan preparation and approval

The LFT&E Plans matrix in the LFT&E strategy identifies which LFT requires a DTP to be submitted to DOT&E for approval or for review and comment. For building-block approach LFTs that do not require DOT&E approval, the DTPs will be approved by the test agency. Coordination and approval of those DTPs will be accomplished in accordance with existing Army T&E policy, and the test agency will forward copies of those DTPs to HQDA for the DUSA(OR) submittal to DOT&E. The DTP is prepared by the Live Fire tester and coordinated with members of the LFT&E working group. Two copies of the DTP (along with two copies each of the previously approved SEP and EDP and SLAD's Pre-Shot Prediction Report) are forwarded to the DUSA(OR) at least 60 days before test initiation. The DTP is either approved for the Army by the DUSA(OR) or returned to the tester for changes or corrections. Once approved by the DUSA(OR), the DTP is forwarded to OSD (DOT&E) for review or approval, as required. Testing will not start until the DTP is approved by the DUSA(OR) and OSD(DOT&E).

S–5. Live Fire Test Detailed Test Plan change procedures

a. For those LFTs not requiring DUSA(OR)/DOT&E approval of the DTP, changes to the DTP are coordinated and approved via existing Army T&E policy (see AR 73–1).

b. For LFTs requiring HQDA (DUSA(OR) and/or OSD(DOT&E) approval of the DTP (as identified in the TEMP, generally FUSL LFTs, the DTP must outline the detailed procedures to be followed to accommodate unexpected changes to the LFT that may occur during actual testing. When a change to the approved DTP is required, it is essential that strict adherence to the change procedures be followed to avoid repeating test shots and to dispel any perceptions of "fixing" the test to achieve desired results. The tester takes the lead in coordinating changes to the DTP and ensures these changes are fully coordinated with all participating LFT&E agencies. Written notification of the proposed changes is forwarded through the DUSA(OR) to DOT&E for approval. No change from the DTP is undertaken until approved by the DUSA(OR) and DOT&E. After DOT&E approval, all participating agencies are notified of the change approval. The change will also be documented in the final test report along with the supporting rationale that is derived from an approved change to the LFT EDP if the change was required as a result of a test design change.

S–6. Live Fire Test Battlefield Damage Assessment and Repair Support Plan

The Battlefield Damage Assessment and Repair (BDAR) Support Plan is prepared by the U.S. Army Ordnance Center and School for FUSL LFTs on ground combat vehicle combat systems and by the U.S. Army Aviation Logistics School for FUSL on aviation systems and defines the level of BDAR to be performed. It describes team membership, repair skill level requirements, and times for repair. The support required by the BDAR team will be decided on a test by test basis in coordination with ATEC's AEC depending on the fidelity of the target. Typically, BDAR teams perform operator/crew, unit, and/or direct support (DS) forward levels of BDAR repairs. The BDAR Support Plan will be submitted to HQDA (DUSA(OR)) and OSD(DOT&E) for approval along with the EDP and DTP for the FUSL LFT and provided to HQ, ATEC for information.

S–7. Live fire test conduct

The following provides general guidance for the conduct of FUSL LFTs and discusses those parameters and functions that must be considered during test planning (for example, vehicle stowage, instrumentation, and scheduling). Actual test requirements will be established on a case-by-case basis to address the data requirements defined in the SEP/EDP. Guidance presented in this chapter is based on Army LFT&E experience to date. Test conduct, test parameters/functions, and the terminology reflect this experience. Because one primary purpose of LFT&E is to address crew survivability, most of the parameters/functions and the testing discussed in this chapter is applicable to any type of

system and the remaining items are easily applied to other types of systems. Again, the reader is cautioned that all requirements must be determined on a case-by-case basis.

a. FUSL Vulnerability LFTs are conducted to identify potential system integration vulnerabilities that cannot be adequately addressed through component and/or sub-system testing. In order to provide the most realistic test possible and to accurately assess the vulnerability of the system and the survivability of the crew, the weapon system must be as close to its combat configuration as possible. Combat configuration denotes a combat configured, fully functional item complete with all sub-systems and on-board stowage items.

(1) The presence of a combat configured, fully functional item with all sub-systems is particularly important in evaluating ballistic damage and the interaction between sub-systems as a result of damage to different components. In order to determine the individual effects of each shot on the test item, the test item is repaired and system functionality is baselined before each test shot. Baseline procedures should include a complete functional check of all major sub-systems on the test item and may also include performance checks for parameters such as engine output.

(2) Systems undergoing LFT are stowed in a combat configuration so that the effects of the stowage on the system vulnerability and crew survivability can be assessed. Stowage in a combat configuration includes ammunition, fuel, additional authorized list (AAL) items, and basic issue items (BII). Anthropomorphic simulants and/or wooden mannequins are located in crew positions as an aid in crew survivability assessments. Ammunition should be live, with inert fuzes or fuzes removed (live fuzes damaged during test conduct could present a hazard to test personnel). However, if the reaction correlation between inert and live ammunition is known and predictable, inert munitions may be stowed to ensure survivability of limited assets (for example, to avoid the premature loss of test items before all the test shots can be completed). The use of inert ammunition instead of live ammunition will be approved via the EDP/DTP approval process on a case-by-case basis. Any planned shot that the PM considers to be catastrophic or of significant damage may be conceded; however, conceded shots will be assigned a Probability of Kill (Pk) = 1.0 for the evaluation.

(3) All fuel in the test item will be at normal operating temperatures for the system at the time of the test firing. This is necessary since the flammability of the fuel increases as its temperature increases.

(4) The AAL and BII are stowed on the test item in accordance with an approved stowage plan. The stowage plan is developed by the responsible TRADOC school and verified by the tester before testing. Crew simulants are dressed in the appropriate ensemble to include helmet, personal weapons, goggles, gloves, boots, coveralls, ballistic vest, and battle dress uniform, as prescribed by Army doctrine. This ensures that the anthropomorphic simulant or wooden mannequin is representative of an actual crew member and that the protective features of the uniform are accounted for in the crew injury evaluation.

(5) A hazard analysis is performed on all of the stowage items. Any stowage item that could pose a hazard to test personnel, if damaged during testing, must be modified or replaced. Those items modified or replaced must be listed in the EDP/DTP. For example, certain types of chemical detectors used on combat vehicles contain a radioactive isotope as part of the sensor. This isotope would be removed before stowing the detector to avoid contamination of the test site and potential hazard to testers.

b. The focus of FUSL Live Fire Lethality Tests is to demonstrate the effectiveness of U.S. munitions against representative threat target(s). However, the test approach is somewhat different than that for vulnerability tests. Although it is desirable to configure the threat system target in a full combat configuration (that is, fully operational and stowed per an approved stowage plan), the target condition, system repair capability, and repair parts availability may require acceptance of some limitations. The FUSL Live Fire Lethality tests generally provide a mechanism for evaluating munition effectiveness against realistic targets based on the contributions of principal damage mechanisms such as penetration/perforation and spall. However, in order to avoid a premature loss of a threat target, it may be necessary to minimize the potential for an early loss of the target from fire by minimizing the use of fuel and munitions/combustibles on the threat target. This may result in accepting some limitations with regard to assessing the contributions of fire, blast overpressure and toxic fumes on system loss of function and crew casualties. The use of inert ammunition in lethality LFT&E targets may be prudent since it is important to investigate the contribution of the primary damage mechanisms to system damage in a limited number of shots and impacts into stowed ammunition may represent only a limited number of likely shot lines.

S–8. Live fire test resources

The full-up system level LFT is normally the last test to be conducted before the FRP DR and, as such, planning and resourcing must be addressed early-on in the LFT&E program. The strategy and resource requirements (to include targets/munitions, and an overview of On-Vehicle Equipment/BII and spare/repair parts) to accomplish an efficient and effective LFT&E program to include building block approach tests must be included in the TEMP T&E Resource Section (that is, Part V).

S–9. Live fire test schedule

Conduct of the FUSL LFT is driven by the time required between shots to repair the target. Full-up system tests, especially vulnerability tests, may require extensive repairs and repair time. Experience indicates that there is roughly a three-to-one ratio of repair time to test range time. To increase test efficiency and provide maximum utilization of

personnel and hardware, it is advantageous to conduct LFTs with multiple target assets. Multiple target assets allow for overlapping of test and repair time, thus, increasing testing efficiency. When multiple test assets are not feasible, the LFT&E schedule must reflect the total time estimated to complete the testing to include repair times. If the schedule cannot accommodate these time requirements, it may be necessary to restructure the strategy. Decisions concerning assets, schedules, and strategy are addressed by the LFT&E working group and reflected in the LFT&E strategy. As with other phases of the T&E process, unresolved issues are forwarded to higher headquarters for resolution.

S–10. Live fire test instrumentation

A complete set of data must be gathered on each shot to facilitate the crew casualty and system damage assessment, to measure and/or record test conditions, and to ensure test conformity (that is, compliance with the EDP/DTP). In addition to instrumentation for addressing crew casualties and system damage, the test item is generally instrumented to provide early warning of potential problems resulting from the test event. Parameters measured could include: engine RPM, voltage, hydraulic fluid pressures and temperatures, oil pressures and temperatures, coolant temperatures, and automatic fire suppression/fire extinguishing system discharges. Actual instrumentation suites are determined by the tester on a case-by-case basis to address the SEP/EDP/DTP data requirements and test item safety/security requirements. These instrumentation packages typically include the following for FUSL Vulnerability LFTs:

a. Video and high-speed photography to provide visual documentation of the test event. Video documentation provides real time monitoring of the interior and exterior of the test item. The exterior video also assists in locating parts displaced by the munition/target interaction. The internal video provides real-time information on perforation of the target protective system, the presence and extent of internal fires, and test item status information required for determining when it is safe for test personnel to re-enter the test site.

b. Projectile flight/performance instrumentation to record striking velocity, pitch/yaw at impact for dynamically fired munitions, and warhead timing data as appropriate (for example, tandem warheads). Video cameras, high speed cameras, and/or flash x-rays may be used.

c. Toxic fumes instrumentation to record the levels of potentially hazardous gases (for example, nitric oxide, nitrogen dioxide, carbon monoxide, carbon dioxide, hydrogen fluoride, hydrogen bromide, cyanide, and aldehydes) and airborne particulates. Toxic fume data are collected at crew member locations. Specific items and crew locations to be sampled are system dependent and will be determined based on an analysis of the potential hazard posed by on-board materials.

d. Thermal effects instrumentation to record temperature and heat flux data related to the crew and test item. These data are used to assess crew survivability, provide engineering data to assess hardware vulnerability, and ensure compliance with the EDP/DTP parameters (for example, fuel temperature at shot time).

e. Blast overpressure instrumentation to record pressure time histories. Overpressure data are collected in the crew compartment and external to the test item to assist in assessing personnel casualties and to provide engineering data to assess hardware vulnerability.

f. Ballistic shock instrumentation to record accelerations and forces on the crew and critical system components. Accelerometers, strain gages, and/or velocity gages can be placed on components to measure the ballistic shock transmitted through the structure of the test item to the components, and on anthropomorphic simulants, where appropriate, to measure acceleration and forces transmitted to the crew. When used, instrumented anthropomorphic simulants are positioned in crew locations away from the primary penetrator path/spall cone to avoid destruction of expensive test equipment and the loss of test data. Wooden mannequins can be placed in other crew locations to record the effect of the penetrator/spall cone.

S–11. Live fire test facilities

Live fire testing often requires extensive test facility capabilities to allow for realistic and cost effective testing. Actual facilities for a given program will be driven by the test and data requirements. Test facility capabilities that could be required to support a given program are as follows:

a. Multimunition firing. The threat could consist of gun fired projectiles, missiles, rockets, and mines requiring a variety of launching/firing capabilities. Threats could require real range firings, reduced range firings, and static firings (for example, mine firings in prepared soil with specified density and moisture content). Launch conditions could be direct fire, super-elevation (that is, anti-air simulation), or high angle of fall (that is, indirect fire simulation).

b. Instrumentation suite. FUSL Live Fire Testing may be instrumentation intensive and could require upwards of 200 channels of data collection during any given shot. Substantial video and high-speed film coverage for documentation and test item security could be required.

c. Range/test item security. In addition to video to provide real-time visual security, an auxiliary fire suppression system could be required to protect range and instrumentation suite facilities as well as test item security. Providing adequate protection to instrumentation cables from fragments and/or fire to ensure test requirements are not compromised must be a prime consideration. Additionally, environmental protection in accordance with Federal and State government mandates must be adequately addressed. Environmental impact statements must be developed, staffed, and approved before test initiation.

d. Repair facility. Because test assets are limited and FUSL LFT&E test item/target configuration requirements are stringent, the ability to perform repairs will be necessary. These repairs could include welding, machining, fabricating/replacing damaged components, and major reconstruction of the test item. Repair up to depot level could be required.

S–12. Test discipline for full-up, system-level live fire test

The high-visibility and oversight of LFT requires strict discipline during the conduct of the testing. LFT phases other than the FUSL LFT will generally be managed and executed in accordance with existing Army T&E policy (see AR 73–1) unless specific LFT considerations warrant otherwise and are reflected in applicable test planning documentation.

a. Adherence to the DTP. One of the primary responsibilities of the tester is to ensure that the test is conducted in accordance with the HQDA/DOT&E approved DTP. Unauthorized deviations from the DTP are not permitted. Additionally, the LFT will not start until the DTP are approved. With FUSL LFTs generally scheduled near the critical full-rate production decision review and test shots relatively expensive, it is essential that the DTP be followed to avoid potential problems. Conducting the test according to an approved DTP will eliminate the perception of bias or of rigging the test in order to ensure positive results. Changing shotlines, threats, and stowage even for sound technical reasons, without proper coordination and authorization, is not permitted.

b. Change procedures. A LFT is rarely conducted without some deviation from the approved DTP being required. To address these potential deviations and retain testing integrity, a strict procedure has been adopted for approving changes to the DTP as described in paragraph S–5.

c. Reporting emerging results. The dissemination of emerging results provides test participants a continuing awareness of test progress and an early identification of potential vulnerability/lethality shortcomings. Damage Assessment Meetings (DAMs) that are scheduled and moderated by the DAT chair should be held periodically throughout the test so that data can be reviewed, commented on, and necessary subjective judgments reviewed for consistency and soundness. Representatives of the damage assessment team (DAT), PM, and system contractor are typically present at these meetings. However, it should be noted that in assessing the shots, the PM and system contractor are present to provide information on system design characteristics, if required. The DOT&E will have access to these meetings; however, any results addressed during these meetings and used in the DOT&E assessment report will be provided to the Army for factual review before its use. Emerging data from the DAT, generally in the form of summary charts incorporating results of deliberations during the DAM, will be marked to indicate that the data are draft or in preliminary form. Emerging results and all finalized damage assessment data will be released by the DAT to the tester and system evaluator for use and secondary distribution as required by T&E protocols.

S–13. Damage Assessment Team for full-up, system-level live fire test

After each shot, the target is examined and the system damage and crew casualties are assessed. This section defines the Army approach to this process. The DAT is the team that collects and assesses crew incapacitation and/or test item/target damage after each shot. The DAT is chaired by SLAD and will include the tester (for all tests) and the user (for vulnerability tests only) as members. The DAT will consult with other organizations as needed for technical expertise or input. All such subject matter experts will be acknowledged in emerging and final damage assessment results. The specific tasks of the DAT are to—

a. Document any physical damage to the simulated crew members and assess the extent of their injuries (that is, level of incapacitation).

b. Document any physical damage to the test/target item.

c. Determine if any injury, degradation, and/or loss of system capability occurred that would affect the ability of the crew and system to perform their mission.

d. Determine the damage mechanisms causing any injury, degradation, and/or Loss of Function (LOF).

e. Characterize the test item's performance and other parameters, before and after each shot, to allow for future vulnerability reduction/lethality enhancements.

f. Document and characterize behind-armor effects produced by the test munition.

g. Use the preceding information to assess crew casualties and determine system loss of function or degraded combat utility for the test munition.

h. Document the final damage assessment for each shot. Necessary subjective judgments will be based upon the majority viewpoint of the DAT. The damage assessment results for each shot are documented in the Final Test Report prepared for the LFT.

S–14. Crew vulnerability for full-up, system-level and system level live fire tests, when appropriate

Crew vulnerability can be assessed by examining data collected with crew simulants and crew environment instrumentation.

a. Crew simulants can be used to support an assessment of expected incapacitation of crewmembers. The following simulants have been used in previous LFTs:

(1) Fully combat dressed wooden mannequins placed in crew positions in the expected penetrator path/spall cone

where acceleration injury is not a main concern. After each shot, the fully combat dressed mannequins are assessed for damage (for example, burns on clothing, damaged body parts, fragment penetration/perforation, and similar changes).

(2) Fully combat dressed anthropomorphic simulants (that is, "anthros") placed in crew positions where acceleration is the main concern. "Anthros" can be used to measure triaxial acceleration, compression, biaxial bending, fore-aft bending, and neck shear.

b. The crew compartments can be instrumented to collect thermal, toxic fumes, and blast overpressure data. The following crew environmental data have been collected in previous LFTs:

(1) Temperature and heat flux levels at each crew member location. These data allow a determination of the level of burn damage and the effectiveness of the crew member's protective uniform.

(2) Toxic fumes levels at each crew member location. Data on toxic gases, pyrolysis products, and airborne particulates are collected.

(3) Blast overpressure levels at each crew member location. These data are used to determine the level of crew incapacitation due to injury to the air containing structures of the body (for example, lungs and ears).

c. The collected crew simulant and environmental data are analyzed and compared to approved crew injury criteria to determine an expected level of crew incapacitation. These data are used by SLAD in the overall crew survivability assessment.

S–15. Vehicle vulnerability for full-up, system-level (and system level live fire tests, when appropriate)

After each individual shot, all damage is recorded, as well as obvious vehicle functional degradation (that is, engine will not run). This damage assessment is then used to determine vehicle vulnerability in the form of system loss of function or degraded combat utility. These estimates are derived through the use of fault-tree or deactivation diagrams. Specific kill criteria to be used will be determined by the DAT chair and the system evaluator for each specific LFT program.

a. In addition to providing insights into system vulnerability, LFT&E programs can provide the soldier hands-on experience in BDAR. BDAR efforts conducted in conjunction with FUSL LFTs can provide the user insights into the time, parts, tools, and skills required to repair the system or to upgrade a damaged system to a combat-capable condition. Evaluation of a system's capabilities immediately following a simulated threat attack compared to the system's capabilities following operator/crew, unit, and DS BDAR provides insights into the effectiveness of BDAR techniques, tools, and training.

b. Another aspect of the LFT&E process is to examine the spare part supply line to ensure that parts stocked are in fact those required to support damage sustained from a battlefield encounter.

S–16. Final Test Report for full-up, system-level live fire tests

The Final TR, prepared by the tester/DAT, provides a formal detailed record of the test data and information obtained during the conduct of the LFT, and describes the conditions that actually prevailed during test execution and data collection. The test report documents all individual shot test conditions and test results required by and identified in the DTP and approved changes to the DTP. The Final TR is provided to the DUSA(OR) for approval 60 days after test completion, as well as to the system evaluator. The approved Final TR and SER must be forwarded to DOT&E within 120 days after test completion and 45 days before the FRP DR. Schedules must be planned accordingly to accommodate these mandatory reporting milestones.